TRANSPORT CONTAINER FOR WIND TURBINE BLADES

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DESCRIPTION OF THE INVENTION

Field of the Invention

[001] The present invention relates to transportation containers. In particular, the present invention relates to apparatuses and methods for containing and transporting wind turbine blades.

Background of the Invention

[002] Turbine blades, such as wind turbine blades used to generate electrical power from the wind, are precision made instruments and can be extremely large (e.g., some exceeding 160 feet in length and 12 feet in width). These large turbine blades require protection while being transported from where the turbine blades are manufactured to the site where the turbine blades will be used. Because of their fragility and size, design of containers for transporting wind turbine blades poses many challenges and obstacles that need to be overcome.

[003] One challenge in designing containers for transporting large turbine blades is that the container should protect the blades from damage that would degrade their performance. In other words, strong containers are required to protect the turbine blades during transport.

[004] Another challenge associated with designing a container large enough to contain a wind turbine blade is that the container should be designed to minimize its weight to reduce transportation costs yet still be strong enough to protect the turbine blade. In addition, since the turbine blades come in a variety of different sizes and shapes, a preferred container would be capable of

accommodating the various different types of turbine blades. Having all the containers sized to fit the largest blade would create unnecessary weight and space when transporting smaller blades.

[005] An alternative to using containers uniformly sized to the largest blade is to create different containers for different sized blades. This option, however, would create a complex logistical problem of ensuring that a container of the proper size was available for each shipment. This problem is exacerbated by the fact that transport of wind turbine blades is sometimes accomplished by sending the blades across oceans on slow-moving vessels. Further, this option would increase the manufacturing cost of the containers due to size variations in the manufacturing process.

[006] In an attempt to overcome the above-mentioned problems related to variable sized turbine blades, sectional container systems have been proposed. Conventionally, 40-foot sectional containers that can be bolted together to create a longer container have been available for containing wind turbine blades. However, processes involved with connecting and separating the sectional containers are cumbersome and time-consuming. Furthermore, since the conventional containers used for wind turbine blades are constructed with a lattice frame design whose structural strength is typically limited, the conventional containers may be subject to fracture during the loading and offloading processes because long wind turbine containers are loaded on and off of transportation media as one unit. This limitation on the structural strength restricts the length of the container system, preventing accommodation of the largest turbine blades.

[007] Another challenge associated with designing a large container is that the container should be compatible with different modes of transportation.

For example, the container should be easily adaptable for transportation by ship, truck, or rail. Conventionally, the containers for wind turbine blades are loaded onto trucks, such as a flat bed truck. One of the problems associated with transporting large loads overland is the height restriction of the load. For example, in some regions, the container height cannot exceed, for example, 4.2 meters (13.7 feet). Such height restriction is to ensure that the container can pass under bridges and overpasses located on the overland transport route. Therefore, reduction in the container height is desirable so that the load height can be made as low as possible.

[008] Another problem associated with the conventional containers for turbine blades is the fact that the containers are not stackable on top of each other. Since conventional containers have their tops opened, the containers cannot be stacked in layers without damaging the blade contained in the bottom container. Furthermore, since the frame of the conventional containers are not strong enough, the conventional containers cannot support another containers on the top. Therefore, to facilitate transportation of the turbine blades in a limited space, e.g., in a ship, it is desirable for a container to be stackable in layers to efficiently utilize the limited space.

[009] A container for a wind turbine blade is reusable and, therefore, should be returned after its use. If the container can be easily adaptable to contain other goods besides wind turbine blades, the valuable shipping space can be efficiently utilized on a return trip by containing other types of goods, rather than wasting the valuable shipping space by returning empty. Therefore, another desirable feature of a container for turbine blades is its adaptability for containing other types of goods besides wind turbine blades.

SUMMARY OF THE INVENTION

[010] To overcome the drawbacks and problems described above and in accordance with the purposes of the invention, as embodied and broadly described herein, one aspect of the invention provides an extendable container system for transporting a wind turbine blade comprising at least one module configured to be connected to other modules, and a connecting member positioned at each end of the module for connection between the module and the other module to extend the length of the container system. The module comprises a box-shaped frame and corrugated side walls attached to the frame.

[011] According to another aspect of the invention, a method for shipping wind turbine blades is provided. The method comprises connecting at least two modular containers to form a container that is large enough to fit at least one wind turbine blade, loading the wind turbine blade into the container, and tilting the wind turbine blade so that the widest portion of the wind turbine blade is positioned at oblique angle with respect to the container, such that the height of the container is reduced.

[012] In accordance with yet another aspect of the invention, a method of transporting a wind turbine blade container without a wind turbine blade is provided. The method comprises separating interconnected modular containers of the wind turbine blade container, attaching an end piece to the modular containers, and shipping the modules.

[013] Additional aspects and advantages will be set forth in part in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The aspects and advantages of the

invention will be realized and attained by means of the elements and combinations particularly pointed out in the appended claims.

[014] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[015] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate various embodiments of the invention and, together with the description, serve to explain the advantages and the principles of the invention.

[016] In the drawings:

[017] Fig. 1 is a perspective view of a transport container containing a wind turbine blade according to an embodiment of the present invention;

[018] Fig. 2 is a side view of a transport container made of two standard modules and two long extension modules;

[019] Fig. 3 is a side view of a transport container made of two standard modules, two long extension modules, and two short extension modules;

[020] Fig. 4 is side view of a transport container made of three standard modules;

[021] Fig. 5 is a perspective view of corrugated sheets of trapezoidal shape according to an embodiment of the present invention;

[022] Fig. 6 is a perspective view of a transport container, illustrating structures of the frame and the walls of the transport container;

[023] Fig. 6A is a perspective view of a retainer according to an embodiment of the present invention;

[024] Fig. 6B is a perspective view of a guiding pin according to an embodiment of the present invention;

[025] Fig. 6C is a perspective view of a tension bolt according to an embodiment of the present invention;

[026] Fig. 7 is a side view of a portion of a transport container with various connecting apparatuses used to connect two modules together;

[027] Fig. 8 is a perspective view of a telescoping column;

[028] Fig. 9A is a side view of a container illustrating placement of telescoping column for a centric lifting;

[029] Fig. 9B is a side view of a container illustrating placement of telescoping column for an eccentric lifting;

[030] Fig. 10A and 10B are perspective views of a blade holder and a blade fitting, respectively, constituting a root fitting;

[031] Fig. 11 is a perspective view of a blade root fitting mounted in a transport container;

[032] Fig. 12 is a perspective view of a blade tip holder;

[033] Fig. 13A is a perspective view of a blade tip holder guiding pin without a locking bar;

[034] Fig. 13B is a perspective view of a blade tip holder guiding pin with a locking bar;

[035] Fig. 14 is a perspective view of a blade tip holder mounted to a transport container;

[036] Fig. 15 is a side view of a transport container configured as a truck trailer with the container connected to wheeled dollies;

[037] Fig. 16 is a perspective view of a transport container configured as two smaller highcube containers.

DESCRIPTION OF THE EMBODIMENTS

[038] Reference will now be made in detail to embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.

[039] As shown in Fig. 1, a container system for transporting wind turbine blades can include various different modules 50, 52 connected together to form a large container 100. Fig. 1 shows a container 100 carrying two wind turbine blades 64, the root portions of each of the wind turbine blades being connected to a respective outer most end portion of container 100. Alternatively, container 100 could accommodate a single turbine blade 64. The container 100 can include at least one standard module 50 and can be extendable in length by attaching extension modules 52 (and/or modules 54, shown in Fig. 3) depending upon the size and shape of the wind turbine blade 64 to be accommodated. In other words, larger extension modules 52 and smaller extension modules 54 can be connected to form an appropriately-sized container 100 to accommodate a particular turbine blade 64.

[040] For example, as illustrated in Figs. 2-4, different combinations of various modules 50, 52, 54 can be utilized to form different container configurations for accommodating various types of wind turbine blades 64. Fig. 2 shows, for example, two standard modules 50 (e.g., 40-ft in length) attached with two extension modules 52 (e.g., 40-ft in length) attached on both ends of the standard module 50. Two additional extension modules 54 (e.g., 20-ft in length)

may additionally be attached to the outer ends of the extension modules 52, as shown in Fig. 3. As shown in Fig. 4, three standard modules 50 can also be attached together. While the lengths of modules 50, 52, 54 described herein are, for example, 40 and 20 feet, these dimensions are exemplary only. In other words, the modules may be any size. For example, the modules 50, 52, 54 can be 20 feet long, 40 feet long, or 60 feet long. Moreover, any relationship between the differently sized modules 50, 52, 54 is within the scope of the present disclosure. Once the modules 50, 52, 54 are connected together to form a large container 100 with a desired length, a wind turbine blade 64 can be loaded into the container 100 and secured.

[041] Referring to Fig. 1, the standard module 50 includes a box-shaped frame 102, corrugated side walls 104, a roof 56, and a floor 120 (as shown, e.g., in Fig. 6). As shown in Fig. 5, the side walls 104 of the standard module 50 can be formed of at least one corrugated sheet 106, 108 made of metal, such as steel. Preferably, the corrugated sheets 106, 108 include alternating ridges 107 and grooves 109, e.g., as shown, so as to form a repeated pattern of trapezoidal corrugation when viewed in cross-section. In the preferred embodiment, two trapezoidally corrugated sheets 106, 108 can be attached to the frame 102 and constitute each of the side walls 104 of the standard module 50. Similar to the side walls 104, the floor 120 may also be formed of the similar corrugated sheets 106, 108. It should be recognized that the side walls 104, as well as the floor 120, can be made of any other suitable rigid materials. The present invention also contemplates that the extension modules 52, 54 can have similar structures as the standard module 50. For example, the extension modules 52, 54 may also include a box-shaped frames, corrugated side walls, a roof, and a floor.

[042] In the preferred embodiment shown in Fig. 5, the corrugations of the corrugated sheets 106, 108 are crossed such that the corrugations of the outer sheet are aligned vertically, while those of the inner sheet are aligned horizontally. It should be understood that the corrugations of the outer sheets may be aligned horizontally and those of the inner sheet may be aligned vertically. This crossed corrugated configuration provides the container with enhanced strength and rigidity required when, for example, the container containing a wind turbine blade is hoisted during loading and offloading processes. The crossed corrugation configuration can also provide the strength and rigidity required for overland transportation, such as a truck trailer or a rail car.

[043] As shown in Fig. 6, the container 100 can be made extendable by attaching other standard modules 50 or extension modules 52, 54 to the standard module 50. Various connecting apparatuses can be provided on the frame 102 or formed as part of the frame 102 to allow connection between the modules 50, 52, 54. In an exemplary embodiment of the invention, a conventionally available retainer 58, e.g., quick-tie, shown in Fig. 6A, can be used. A portion of the frame 102 is configured to communicate with the retainer 58, such that other modules 50, 52, 54 having similar configuration can be connected to the standard module 50 via the retainer 58. For example, the frame 102 may include an insertion hole 61 formed on the frame 102 and configured to adapt the retainer 58. Preferably, each distal end of the retainer 58 may form substantially rectangular head 88, so that, after the rectangular head 88 is inserted into the insertion hole 61 (i.e., preferably formed of substantially rectangular shape), the head 88 can be rotated

about 90 degrees to lock the retainer in position. It should be recognized that more than one retainer can be used.

[044] The connection between the modules 50, 52, 54 may also include a guiding pin 93, shown in Fig. 6B, for connection, preferably, in the middle portion of the frame 102. Each end of the guiding pin 93 is configured to fit into respective holes 57 formed on the frame 102. In an embodiment shown in Fig. 6B, the guiding pin 93 includes two connecting bolts 91, 92 each integrally formed of a single piece. The guiding pin 93 includes two contact plates 94, each configured to allow flush contact with a side surface of the module frame 102 when two modules 50, 52, 54 are connected together. Preferably, the two connecting bolts 91, 92 are aligned substantially parallel to each other with a predetermined axial displacement, such that one of the two connecting bolts 91, 92 protrudes longer than the other bolt in each side. The guiding pin 93 provides enhanced structural support between the connected modules 50, 52, 54.

[045] A tension bolt 140 can also be provided at the lower portion of the module 50, 52, 54 to adjust the fastening tension between two connected modules 50, 52, 54. Fig. 6C shows a preferred embodiment of the tension bolt 140, which may be 1 meter in length, for example. The tension bolt 140 is configured to fasten two connecting modules in the lower portion of the modules 50, 52, 54 by passing the bolt 140 through bottom support members 130 fixedly disposed in corners between two adjoining frames 102 of the side wall 104 and the floor 120. The bolt 140 includes a proximal end portion 141 and a distal end portion 149, each configured to hold the bottom support members 130 of the two connecting modules 50, 52, 54 between them. Preferably, the tension bolt 140 includes tension adjustment member 143 configured to adjust the fastening

tension between two connected modules 50, 52, 54. In an embodiment, shown in Fig. 6C, the tension bolt 140 includes a side arm 143 rotatably coupled to the proximal end portion 141 of the bolt 140. In operation, by rotating a side arm 143, the proximal end portion 141 is configured travel along the shaft 145 to fasten or loosen the fastening tension. The side arm 143 may also include a locking pin 144 configured to lock the side arm 143 to a portion of module to prevent possible movement of the side arm 143 during transport.

[046] Fig. 7 shows a portion of the two modules 50, 52, 54 interconnected by utilizing the connecting apparatuses described above. It should be recognized that any other suitable connecting apparatuses may be utilized in place of, or in addition to, the apparatuses described above for connection between the modules 50, 52, 54.

[047] The standard module 50 and the extension modules 52, 54 may include a plurality of telescoping columns 150, as shown in Fig. 7, attached to the modules 50, 52, 54, shown in Fig. 8. One advantage of telescoping columns 150 is that they can permit another module 50, 52, 54 to be stacked on top of a module 50, 52, 54. Further, a roof 56 may be attached using telescoping columns 150 to protect the wind turbine blade 64 from damage, e.g., from falling objects. As shown in Fig. 14, roof 56 can be further supported by a plurality of connecting arms 46 diagonally supporting the center of the roof 56 from the frame 102 of the module 50, 52, 54.

[048] Referring to Fig. 6, the columns 150 may be inserted into hollow passages 101 formed inside the box-shaped frame 102, such that the column 150 can slide up and down within the hollow passage 101 of the frame 102, allowing the height of column 150, and, e.g., roof 56, to be adjusted. It should

also be understood that the column 150 may also be slidably attached to the box-shaped frame 102. Movement of the columns 150 can be performed by human or by a powered system, such as, for example, an electrical motor, hydraulic cylinder, or a pneumatic system.

[049] In an embodiment, shown in Fig. 8, the telescoping column 150 may have at least one stop hole 110, 112 for securing the column 150 at a stationary position by inserting a stop (not shown) in the stop hole 110, 112. The column 150 may also include a cap 61 integrally formed at the top of a shaft 99. The cap 61 can include a connection hole 62 configured to communicate with a connecting apparatus, such as, for example, a quick-tie 58. In this manner, roof 56 can be attached to the telescoping column 150 via a connecting apparatus, as shown in Fig. 7. It should be understood that the roof 56 may alternatively be attached to the column 150 by any suitable manner. It should also be understood that the column 150 may optionally include slides 103 formed on the surfaces of the shaft 99 to facilitate sliding movement within the hollow passage of the frame 102. The modules 50, 52, 54 may optionally be provided with a ladder 111 attached to the outside of the module 50, which provides access to, e.g., the roof 56 or the interior of the container 100.

[050] The columns 150 are preferably placed in each corner of a module 50, 52, 54 and in the middle portion of the side walls 104, as shown in Fig. 1. The number and placement of columns 150, however, may vary depending upon various conditions. For example, any number of columns 150 may be placed in any position to suitably support roof 56 or another module 50, 52, 54, such as four columns 150 placed respectively in each corner of modules, 50, 52, 54.

Also, adjoining modules could be designed to share a column 150, reducing the number of columns 150 needed.

[051] In an embodiment, the number and placement of the columns 150 depend on the container balance during the container lifting process. If the balance of the container 100 is located at the center of the container 100 (e.g., when two blades 64 are contained symmetrically with respect to the center of the container 100 as shown in Fig. 1), a centric lifting, shown in Fig. 9A, can be used. In this case, the telescopic columns 150 may be placed symmetrically in the corners and in the middle portion of the side walls 104. However, if the balance of the container 100 is at a location other than the center (e.g., when a single blade 64 is contained in the container 100), an eccentric lifting, shown in Fig. 9B, can be used. In this case, the lifting apparatus (not shown) may be coupled to asymmetric location of the container 100 and, accordingly, the columns 150 may be displaced asymmetrically in order to balance the container 100 and uniformly distribute the load to the columns 150.

[052] The wind turbine blade 64 can be secured in the container 100 by a root fitting. An exemplary embodiment of a root fitting is shown in Figs. 10A and 10B. The upper portion of the root fitting is a blade fitting 78. The blade fitting 78 can have a plurality of slots 90 for attaching the blade fitting 78 to the root portion of the wind turbine blade 64. The turbine blade 64 is formed with bolt holes in its root portion. The blade fitting 78 is attached to the wind turbine blade 64 by bolting blade fitting 78 through slots 90 to the corresponding holes in the root portion of the turbine blade 64 using, e.g., bolts, washers, and nuts (not shown). After transportation of the wind turbine blades 64, the same bolt holes in

the hub portion of wind turbine blades 64 can be used for assembly of the wind turbine 64 in attaching the root of the blade 64 to the hub of a wind turbine.

[053] Blade fitting 78 can be attached on top of a blade holder 74. Blade holder 74 is essentially a frame 116 which is attached to the interior of a module 50, 52, 54. Pins 82 can be used to attach blade holder 74 to interior of a module 50, 52, 54 by communicating with holes 175 (e.g., shown in Fig. 6) in the module 50, 52, 54. The blade fitting 78 can be attached to the blade holder 74 via an attaching apparatus 84, which communicates with attaching apparatus 86 of the blade fitting 78. The blade fitting 78 may include support frames 201 fixedly attached to the blade fitting 78 and configured to be attached, as shown in Fig. 1, to the frame 102 of the module 50, 52, 54.

[054] Fig. 11 shows the root fitting installed in place within a module 50, 52, 54. Preferably, the root fitting is installed on an outer end of the outer most module 50, 52, 54, as shown in Fig. 1, such that the root portion of the wind turbine blade 64 is placed on the outer end of the outer most module. Blade holder 74 can also include a cylinder 76 which is connected to a pin 188 of the blade fitting 78. The cylinder 76 can cause blade fitting 78 to be tilted to reduce the height of blade 64 when it is contained in container 100. When a turbine blade 64 is attached to blade fitting 78, expansion and contraction movement of cylinder 76 causes the blade fitting 78 and wind turbine blade 64 to be rotated together.

[055] The tip portion of the wind turbine blade 64 can be securely attached to the module 50, 52, 54 by a blade tip holder 98. An exemplary embodiment of a blade tip holder 98 is shown in Fig. 12. The blade tip holder 98 can include a pair of loop bands 92 or slings, a portion of which are secured to

the frame of the module 50, 52, 54 by a tip holder guiding pin 193, shown in Figs. 13A and 13B. The tip holder guiding pin 193 can be a modified guiding pin 93, shown, for example, in Fig. 6B, to attach the loop bands 92 to the frame 102. The tip holder guiding pin 94 includes two contact plates 194, each configured to allow flush contact with a side surface of the module frame 102 when two modules 50, 52, 54 are connected together. Each of the contact plates 194 may form a slot 118 in which a portion of the loop band 92 may be inserted. The blade tip holder 193 can allow installation and removal of the holder 193 at various positions along the interior of the modules 50, 52, 54. It should be recognized that, when a loop band needs to be placed in the connecting portion between two modules 50, 52, 54, the guiding pin 93 can be replaced with the tip holder guiding pin 193.

[056] The loop bands 92 are preferably formed of rubber. Each loop band 92 can have a bar 96 which can be configured to fit in the slot 118 of the tip holder guiding pin 193, shown in Fig. 13A. As shown in Fig. 13B, once the bar 96 of the loop band 92 is fitted in the slot 118, a locking bar 196 is inserted through a receiving member 197, 198 to secure the connection between the loop band 92 and the tip holder guiding pin 193. The loop band 92 may include a connecting member 292 at its top portion, which is configured to be coupled to a portion of the roof 56 or the frame 102 of the module 50, 52, 54. Fig. 14 shows a blade tip holder 98 installed via a blade tip holder guiding pin 193 in the module 50, 52, 54.

[057] Once the modules 50, 52, 54 are assembled together to form a container 100 and turbine blade 64 is installed in the container 100, the container 100 is hoisted onto and secured to a transportation media. As mentioned previously, a second container may be stacked on top of the first container.

[058] Container 100 permits water- and land-borne transportation. Water-borne transportation can take the form of a vessel with suitable storage area (above or below deck) for at least one container 100. For land-borne transportation, the container 100 can be used as the primary container for the transport. For example, container 100 can be used as a trailer for road transport by attaching wheels or dollies 62 as shown in Fig. 15. An example of such dollies is the Euro/Inter Combi-dollies, a standard system for converting box containers into truck trailers. By directly mounting wheels or dollies 62 to the container, reduction in container height can be achieved by eliminating the unnecessary height of a trailer bed. Preferably, each modular container contains two wheels to form a trailer or a container for the transport. Containers 100 may also be transported by rail. For example, container 100 can be placed on three flat-bed rail cars or two containers 100 can be placed on five flat-bed rail cars.

[059] Further reductions in container height can be achieved by tilting the turbine blade 64 inside the container 100. By loading the container such that the widest portion of the turbine blade is diagonally fitted in the container 100, the height of the container 100 can be further reduced. Reduction in container height ensures that the transport system can pass through tunnels and under bridges and overpasses located on the transportation route.

[060] As shown in Fig. 16, once the turbine blade 64 has been transported to the destination site and removed from the container 100, the container 100 can be disassembled to form several smaller highcube containers 121 . The modules 50, 52, 54 constituting a large container 100 can be easily separated by releasing the connecting devices and pulling the modules 50, 52, 54 apart. End portions 122 can be made easily detachable from and attachable

to the ends of the modules 50, 52, 54 using suitable connecting apparatus, such as quick tie 58, pins, or the like. As shown in Fig. 16, end pieces 122 can be attached to both ends of highcube container 121. Optionally, the smaller highcube container 121 may be stored in the larger highcube containers 121. The capability of the modules 50, 52, 54 to be convertible to smaller highcube containers 121 from a large container 100 for the return trip allows the modules 50, 52, 54 to be used to transport other types of goods besides the turbine blades 64. Thereby, the valuable shipping space can be efficiently utilized on the return trip, rather than wasting the valuable transport space by returning empty.

[061] When deciding whether to convert container 100, portions of the container 100 may be omitted from the highcube container 121. For example, a highcube container 121 may or may not have a roof 124. Alternatively, if a roof is desired and the module used did not include a roof, a roof 124 may be added. Further, if the container 121 has a roof 124, it can be configured to be raised or lowered depending on the required cargo space using on or more of telescoping columns 150. Another optional adaptation is that in order to facilitate draining of liquids, such as, rain water in the container, drain holes (not shown) may be provided, e.g., drilled, in the floor (not shown) of the container 114, preferably in grooved sections of the floor.

[062] Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is intended that the specification and examples be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims.